Calibration and Validation of Satellite Sensors at NOAA/NESDIS/ORA: Summary of Methods and Recent Results

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ABSTRACT

The NESDIS Office of Research and Applications performs sensor calibration and data product validation (cal/val) for NOAA's polar and geosynchronous operational environmental satellites, as well as for a number of non-NOAA spacecraft and instruments. This paper summarizes the scope of these efforts, describes some of the unique methods developed and used by ORA and its partners, and presents and discusses selected recent results. Particular attention is paid to the Simultaneous Nadir Overpass (SNO) method for the on-orbit inter-calibration of like sensors on successive iterations of NOAA's Polar-orbiting Operational Environmental Satellites. Developed to check the channel by channel performance of the High Resolution Infrared Sounder (HIRS) instruments on NOAA-17 and -18, the SNO method has now been applied to test the effectiveness of calibration corrections made to Advanced Very High Resolution Radiometer (AVHRR) observations and to Advanced Microwave Sounding Unit (AMSU) data. The use of a network of surface-based GPS receivers to determine atmospheric integrated precipitable water vapor (IPW) accurately and precisely with 30-min temporal resolution now provides an effective and rapid means of validating satellite moisture retrievals. The method has been used successfully to validate observations from the Atmospheric Infrared Sounder (AIRS) and sounders on NOAA's Geosynchronous Operational Environmental Satellites (GOES). Although the method does not provide a vertical profile of moisture, it is shown to provide an effective scaling constraint for satellite and radiosonde intercomparisons.

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INTRODUCTION

The utility of the large and growing volume of satellite observations and derived data products for operational applications such as numerical weather prediction and climate research is dependent on the proper calibration of the instruments and validation of the products. NOAA is both operator of the POES and GOES systems and an end-user of satellite observations provided by a variety of operational and research spacecraft. It is not surprising therefore, that expertise in cal/val has been established at NOAA. These efforts are centered in NESDIS/ORA, however, many of them benefit from the cooperation with other NOAA Line Offices, NASA, other U.S. government agencies, universities, industry, and international partners.

OVERVIEW OF ACTIVITIES

ORA scientists have participated in pre-flight sensor calibration for GOES and POES imagers and sounders. These sensor characterizations permit optimal retrievals and direct data assimilation to be conducted. The extended lifetimes of operational and major research satellites require on-orbit sensor characterization periodically as well. Therefore ORA monitors the radiometric response of passive sensors on orbit, including the targeting of cold space, on-board sources, stable stars, and standard earth scenes for vicarious calibration.

ORA develops new products, refines retrieval algorithms, and guides the transition to operations for new and improved products. Data validation is an integral component of this process. For example, atmospheric motion vectors derived from consecutive scenes for the GOES or MODIS imagers are verified and quality-controlled via comparisons to radiosonde and wind profiler data and analyses. Ocean color data are validated using *in situ* sensors, as are sea surface temperature and surface wind products. The verification of new air quality products based on measurements of aerosol optical depths from GOES and MODIS relies on a variety of correlative data including *in situ* sensors, lidars, and sun photometers. SBUV ozone products are confirmed using Dobson station data Typically ORA relies on its partners to provide the verification data for satellite measurements.

SELECTED RECENT RESULTS

Examples of recent results that are expected to bear on future applications are presented in this section.

a. Simultaneous Nadir Overpass (SNO)

The SNO method (Cao *et al*, 2004) significantly enhances capability to characterize POES sensors on-orbit when a pair of like instruments view the same nadir scene. Recently SNO has been used to reveal seasonal biases in the brightness temperatures of HIRS long-wave (stratosphere) channel on NOAA-15 and NOAA-16. This is illustrated by the blue (top) curve in Fig. 1. The bias is due to the interaction of seasonal temperature differences and the slight spectral response differences.

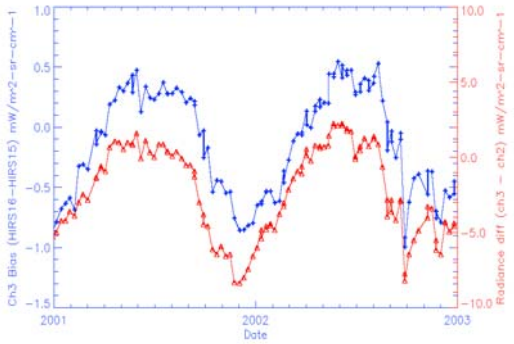

Fig. 1. Seasonal bias (blue, top) in HIRS channel 3 revealed using SNO data.

b. GPS IPW verification for AIRS

With the NOAA Forecast Systems Laboratory, ORA scientists now use surface-based GPS sensors to validate AIRS moisture retrievals over the United States. The 30-min resolution of the GPS data enables significant data sets to be accumulated quickly, as illustrated by the monthly scatter plot in Fig. 2. There is very high correlation overall, but indications that the AIRS retrieval may be biased too dry/wet in wet/moist atmospheres, respectively. GPS IPW is being used as a constraint for validating AIRS vertical water vapor profiles (McMillin *et al*, 2005) and to evaluate

the GOES sounder moisture products at asynoptic times (Birkenheuer, *et al*, 2005) also.

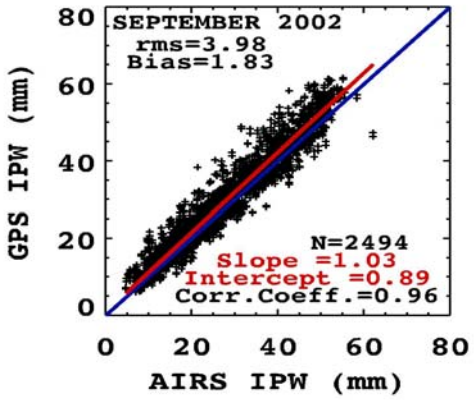

Fig. 2. Scatter plot of matched GPS and AIRS IPW data over the United States.

c. Multi-sensor NDVI validation

Normalized differential vegetation index (NDVI) are shown in Fig. 3 for a scene dominated by corn fields during the growing season. MODIS and AVHRR data give excellent agreement in this case. Reproducing a like result using different sensors is a key goal for a requirements-based observing system.

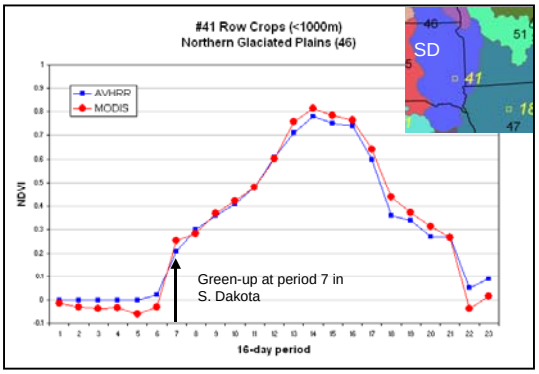

Fig. 3. NDVI estimates of a single scene from AVHRR (blue) and MODIS (red.)

However, reproducing like results requires adequate instrument calibration. For example, the differences in AVHRR spectral response functions generate very different NDVI estimates for the same scene, as shown in Fig. 4.

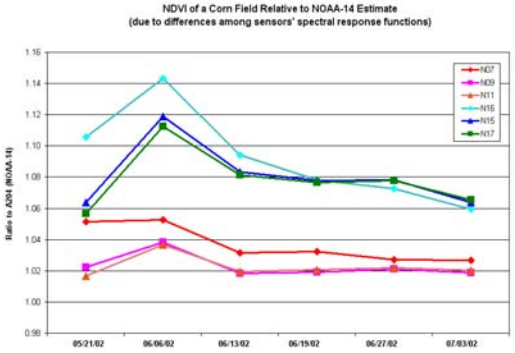

Fig. 4. Ratios of NDVI values from 6 AVHRR instruments relative to the corresponding NOAA-14 values.

SUMMARY

As the quantity of sensors and products grows, ORA refines and applies proven cal/val methods and develops new ones. These efforts depend on partners. Global monitoring over extended periods in the future is expected to require even more rigorous inter-calibration in the future.

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